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AUTHOR Malm, Kaj
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ABSTRACT

The development and testing of a process model of undergraduate student performance and the influence of performance on dropout rates are discussed. An important feature of the model is a feedback loop that represents knowledge of results. A mathematical elaboration of traditional ideas regarding the effect of feedback on performance is included. A differential equation is obtained when the rate of change in the performance of a student at some point in time is proportional to the performance at that time minus some constant (which is a measure of the performance norm adopted by the student). The solution of the equation is the performance function, and its outstanding feature is its monotonicity. Testing of the model was undertaken with about 2,000 undergraduates enrolled in a 1-year mathematics course at the University of Helsinki, Finland, during 1975-1980. Each year, students were divided into those who failed and those who passed, and data were collected on performance and numbers of participants on seven examinations. The number who passed divided by the number in the last examination was remarkably stable through the 5 years. About 15 percent of the students participating in the last examination failed, and almost 90 percent of those who failed dropped out before the last examination. The total dropout rates were therefore more or less complementary to pass rates. Relative performance and mean standard deviations of the scores were also assessed. It is concluded that the theory explained 88 percent of the dropout variance and 81 percent of the variance of the pass rate. (SW)

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Department of Education

University of Helsinki

RESEARCH BULLETIN 58

Kaj Malm

ON THE DYNAMICS OF UNDERGRADUATE PERFORMANCE AND DROPOUT

U.S. DEPARTMENT OF EDUCATION
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INTRODUCTION

In the vast literature on college dropout many synonyms have been used for the term dropout: wastage, failure, mortality etc. The main criterion for classifying a student as a dropout seems to be his failure to obtain a degree; for instance the following is a typical definition: "Wastage is defined to include all students who enter in a given year and leave without achieving the qualification for which they enrolled to study (Robbins 1963, 125)". It is noteworthy that dropout and failure are commonly identified (e.g. Fulton 1977, 33), although these concepts sometimes are separated at least as far as terminology goes (Kallós 1970, 131). These concepts are, however, not identical; of course a dropout implies failure, but conversely a failure need not have a dropout as an antecedent. One can (at least at Finnish universities) join all the courses and examinations needed for a degree without passing some crucial examination. The criterion for dropout proposed here is that the student does not show up at some compulsory course or examination, or after having joined some course does not complete it. Stated in this way the definition of dropout is quite unambiguous. On the other hand the criteria for failure vary considerably. For instance the following have been used: "... attrition rates have been computed on a graduate-in-four years basis; on a graduate-in-four-years-or-still-enrolled basis; on a graduate-eventually basis (Summerskill 1964, 629)."

Evidently the identification of dropout with failure has led to a conception of the dropout problem on a level where the details of the actual didactical process have not been allowed to intrude. A sizable part of those dropout studies which are not pure surveys aim at finding determinants of attrition (or, complementarily, success). One of the more massive ones is due to Lehtovaara (1966), and others include the extensive series by Sigqvist-Saltzman (e.g. 1970 and 1974). Typically, in this kind of studies correlations are computed between school subject marks and measures of performance at the university level. Although positive correlations are commonly found, they are sometimes quite low (Sigqvist-Saltzman 1970, 184), and, besides, almost

trivial from a theoretical point of view as little is proved beyond (to wit) the stability of ability. Kallós (1970, 130), for one, is of the opinion that the interaction between process variables and other variables has not been studied as much as it deserves. The same kind of conclusion is arrived at by Lauvås (1970, 103).

As implies above an important reason for the criticism is the fact that attrition has been studied on a very coarse scale, corresponding to the model in fig. 1.

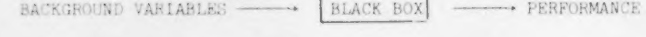

Fig. 1.

Here only background variables are related to performance and the black box represents the various aspects of the process which are not elucidated by the background data of most studies. The experience of university teachers, however, suggests that the dropout problem manifests itself very clearly on another level, namely at the courses which are an important part of the university curriculum. Attendance tends to decrease, both at lectures and examinations. Of course this simple observation does not constitute a sufficient reason for research on this level, but the point is that the course level is crucially important for overall failure and dropout as it is natural to assume that a student bases his conclusions regarding his prospects on the cumulative experience gained at the courses. It is the more surprising that the course level has been neglected as it should be clear that this level is the one where educational improvements can be implemented most efficiently if one wishes to change the failure rate.

The aim of this study is to give a more differentiated (albeit not complete) model, and to test this model. To this end data are collected not only on global failure or success, but also on changes in performance during the learning process.

1. A PROCESS MODEL FOR PERFORMANCE

In this section a simple model for success and failure will be constructed. An important feature of this model is a feedback loop which represents that "knowledge of result" treated by i.a. Annett (1969). In this case it is assumed that the subjects are participants of a course comprising several examinations, the total outcome being completely determined by the scores of these examinations. As a starting point it is assumed that the outcome of an examination exerts influence on continuing participation and also on the effort expended (Atkinson 1974, 307). The segment of the proposed model corresponding to a single course is given in fig. 2.

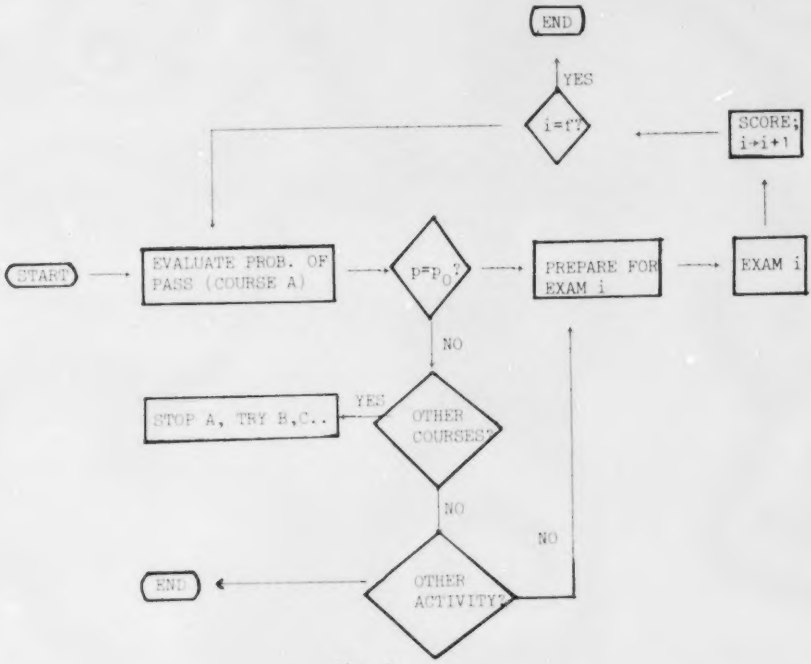

Fig. 2.

If, at the outset, the subjective probability of an ultimate pass surpasses a threshold value p_0, the subject is supposed to prepare for the first

examination ($i = 1$), record the resulting score and repeat the sequence with $i = 2$. This process may be repeated until $i = f$, where f is the last examination, or until p_0 is not reached. If the outcome is not satisfactory there are various ways out; early in the term a transfer to some other course might take place, and if this is excluded, nonacademic alternatives might be considered by the subject. Certainly there is also the option of continuing in spite of discouraging outcomes.

Every course has a corresponding component of the model, and these components are connected according to the priorities imposed by the overall goal of the subject.

One of the drawbacks of models of the kind discussed above is that it is easy to interpret phenomena in terms of them, but hard to obtain numerical predictions. At this stage, therefore, an additional assumption will be made regarding the feedback loop. Let the performance of a subject at a given time be denoted by y and let y' be the time derivative. Let furthermore y_a be some norm which the subject uses to assess his own performance. The assumption can now be written as a differential equation:

$$(1) \qquad y' = c(y - y_a).$$

Here c is a parameter which is a measure of the strength of feedback. It is interesting to compare this with the theory of Atkinson (1974, 14 and 38); eq. 1 does not follow from that theory but is quite compatible with it. If y_a is interpreted as a level of aspiration, eq. 1 implies results which have been verified empirically, e.g. by Worell: "The student ...who believed that he would not achieve considerably beyond what he already has ...tended to be successful (Worell 1959, 54)."

The solution of eq. 1 is quite simple:

$$(2) \qquad y = y_a + (y_0 - y_a)e^{ct},$$

where t is time, y_0 the performance at the time $t_0 = 0$. If t is approximated by the order of an examination, and if t_0 is identified

with the time of the first examination, an approximation of the performance at the i:th examination is given by the following:

$$(3) \qquad y_i = y_a + (y_0 - y_a)e^{c(i-1)}.$$

The solution is obviously monotonous: increasing if $y_0 > y_a$, constant $(= y_0)$ if $y_0 = y_a$ and decreasing if $y_0 < y_a$. Moreover, for small values of c and i the solution is nearly linear.

Equation 3 is easily generalized to a population regardless of the distributions of y_0 and y_a. If c is held constant, the mean performance is given by

$$(4) \qquad \bar{y}_i = \bar{y}_a + (\bar{y}_0 - \bar{y}_a)e^{c(i-1)}.$$

2. PROBLEMS AND PREDICTIONS

Stated in general terms the problems considered here are the development of performance during a course and the influence of performance on dropout rates. More specifically, testably predictions are derived from the proposed model.

On the basis of eq. 1 the dropout rate (after each examination) can be predicted quantitatively only if the distributions of y_a and p_0 are known. On the other hand qualitative results can be obtained. As the model implies that a course is abadoned whenever the probability of a pass is less than p_0, low means should imply high dropout rates (here the dropout rate for examination i is defined as the number of participants in examination i who do not participate in any subsequent examination, divided by the total number of participants in examination i); the results of Nisbett & al. (1975) to the effect that knowledge of base rates affects predictions very little should rule out the interaction between the mean score of an examination and p_0. Thus the first prediction is obtained:

HYPOTHESIS 1. The dropout rate correlates negatively with the mean score.

As the total dropout rate in the case considered in the next section is more

or less the complement of the pass rate, the following prediction is a corollary valid for that case:

HYPOTHESIS 2. The pass rate correlates positively with the sum (or mean) of the mean scores of the examinations.

One would be inclined to believe that equation 4 as such gives a testable prediction. There are some difficulties, though. The measured score s no doubt is a function of y: $s = s(y)$, but this function need not be linear. Moreover, the score is influenced by other factors, not least by the level of difficulty. As there is no independent way to estimate that level, a somewhat indirect course must be taken. If the level of difficulty operates roughly multiplicatively, one can eliminate it by considering two subpopulations 1 and 2. By equation 4 one then obtains

$$\bar{y}_{i1}/\bar{y}_{i2} = \frac{(\bar{y}_{a1} + (\bar{y}_{01} - \bar{y}_{a1})e^{c(i-1)})}{(\bar{y}_{a2} + (\bar{y}_{02} - \bar{y}_{a2})e^{c(i-1)})}. \tag{5}$$

If this quotient is denoted by q_i and if $\bar{y}_{a1} = \bar{y}_{a2} = \bar{y}_a$, the equation can be written

$$q_i = (1 + a_1 e^{c(i-1)})/(1 + a_2 e^{c(i-1)}), \tag{6}$$

where $a_1 = (\bar{y}_{01} - \bar{y}_a)/\bar{y}_a$ and $a_2 = (\bar{y}_{02} - \bar{y}_a)/\bar{y}_a$. If furthermore $\bar{y}_{02} = \bar{y}_a$, equation 6 assumes the simple form

$$q_i = 1 + ae^{c(i-1)}, \tag{7}$$

where $a = a_1$. Comparing the obtained scores with theoretical values one then obtains a new prediction, namely that equation 7 describes the observed quotient $\bar{s}_{i1}/\bar{s}_{i2}$. To simplify notations the latter quotient will be referred to as the empirical q-value, while the theoretical q-value is that given by eq. 7.

HYPOTHESIS 3. For two suitable subpopulations the empirical q-value is approximately equal to the theoretical one.

Because the nonlinearity of the function $s = s(y)$ has been disregarded in hypothesis 3, there will be a residual effect, the magnitude of which should depend on s (or y). This is easily seen if $s(y)$ is assumed to be as in fig. 3.

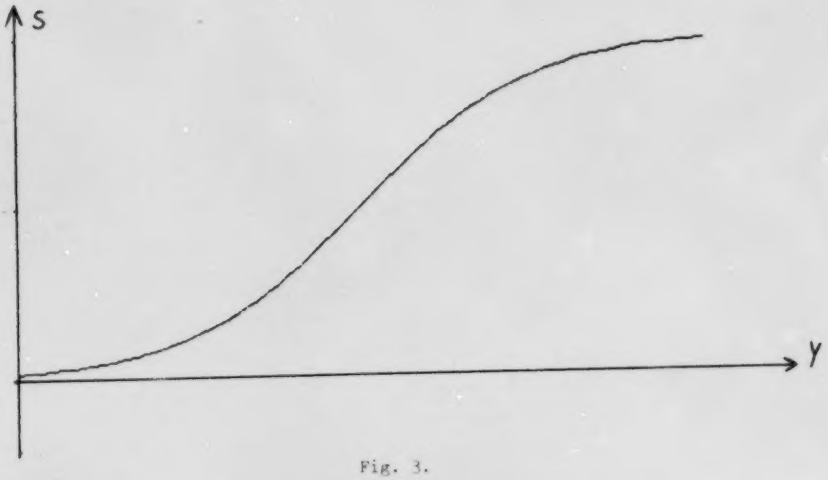

Fig. 3.

As $s(y)$ is bounded and certainly increasing and as y can be assumed to obey a normal distribution, it is likely that a function such as that depicted in fig. 3 is essentially correct; at least is explains the observed skewness of the score distributions of extremely easy and difficult examinations. Thus a fourth prediction is obtained.

HYPOTHESIS 4. The difference between the theoretical and empirical q_i correlates with $\bar{s}_{i1}$ (and $\bar{s}_{i2}$).

By eq. 2 the standard deviation of y increases with time, and this results in an increasing standard deviation of the measured score s, at least for values corresponding to the almost linear middle part of the function $s = s(y)$ (fig. 3).

HYPOTHESIS 5. The standard deviation of s increases with time.

3. METHOD

3.1. The course and the subjects

The subjects were those undergraduates who enrolled on an one year course in analysis given at the department of mathematics of the university of Helsinki during the five consecutive years 1975-1980. Each year more than 400 students enrolled. The length of the course and the exceptionally high number of examinations (seven) are obviously important in connection with hypotheses 3-5. Each year three exams were given during the autumn term, four in the spring. Every examination comprised four items scored 0-6, and thus the maximum score was 24 points and cumulatively 168 points. To pass a subject had to obtain 71-80 points; the actual limit fluctuated slightly from year to year.

3.2. Procedure

For every year 1975-1980 the students of the course were divided into two groups; group 1 contained the students who failed in the end, group 2 those who passed. For these two groups data were collected on performance and numbers of participants in the examinations. Mean scores and standard deviations of the scores were computed. The fraction of students who passed was deduced from these figures, likewise the dropout rate of every examination. The correlations of these variables with suitable mean scores were computed. The mean scores of group 1 divided by the corresponding means of group 2 were computed and to the resulting mean curve the theoretical one (eq. 7) was fitted. The correlation between the theoretical and empirical values was computed, and the differences between the two curves were compared with the mean scores of the corresponding examinations. Finally the standard deviations of the scores of the two groups were subjected to trend analysis.

4. RESULTS

4.1. The dropout rate

The number of those who passed divided by the number of participants in the last examination was remarkably stable (mean = 0.86, SD = 0.03) through the

years 1975-1980. Thus about 15% of the subjects participating in the last examination failed. As only about 50% of the participants in the first examination went on to the last one and as practically everybody who passed participated in every examination, almost 90% of those who failed dropped out before the last examination. Thus total dropout rates were more or less complementary to pass rates.

As a check on hypothesis 1 the dropout rates of the examinations were related to the corresponding mean scores by regression. The decision to do this separately for each examination was taken because the examinations are not quite comparable, as for instance the third examination occurs prior to the Christmas recess and a new term with a fresh choice of courses follows. The results are given in table 1.

Exam	1	2	3	4	5	6
Correlation	-.44	-.60	-.85	-.01	-.77	-.74
Slope	-.47	-.90	-1.12	-.02	-.98	-1.16

Table 1. The correlation between dropout rates and mean scores.

Only one significant ($p < 0.05$) correlation is obtained. However, the correlations for the fifth and sixth examinations are close to the significance limit, and the fact that every correlation is negative is significant ($p < 0.02$) per se. It deserves notice that the slopes for the three examinations with the highest correlations are nearly identical.

To check hypothesis 2 the grand means of the scores and pass rates were computed (table 2).

Year	75-76	76-77	77-78	78-79	79-80
Grand mean	11.18	11.71	10.62	11.74	12.16
Pass %	42.0	43.0	32.3	43.9	44.3

Table 2. Pass rates and mean scores.

The correlation is quite high, $r = 0.90$ ($p < 0.05$). Thus hypothesis 2 obtains some degree of confirmation.

4.2. The relative performance

The empirical q-value, i.e. the ratio $\bar{s}_{i1}/\bar{s}_{i2}$ was defined on the basis of two subpopulations. In the present context these are identified with the groups 1 and 2 as defined in 3.2. Group 2 is relatively easy to handle because (as noted earlier) practically no changes in the size of that group occur during the length of a course. The condition used in the derivation of eq. 7, namely that $\bar{y}_2$ is constant over the examinations, can not be checked directly, but by analysis of variance the constancy of $\bar{s}_2$ over the examinations was checked. If the coefficients of eq. 7 are chosen to make the theoretical and empirical q-curves meet at the endpoints (i = 1 and i = 7), the values $a = -0.309$ and $c = 0.087$ are obtained and the resulting curves are shown in fig. 4.

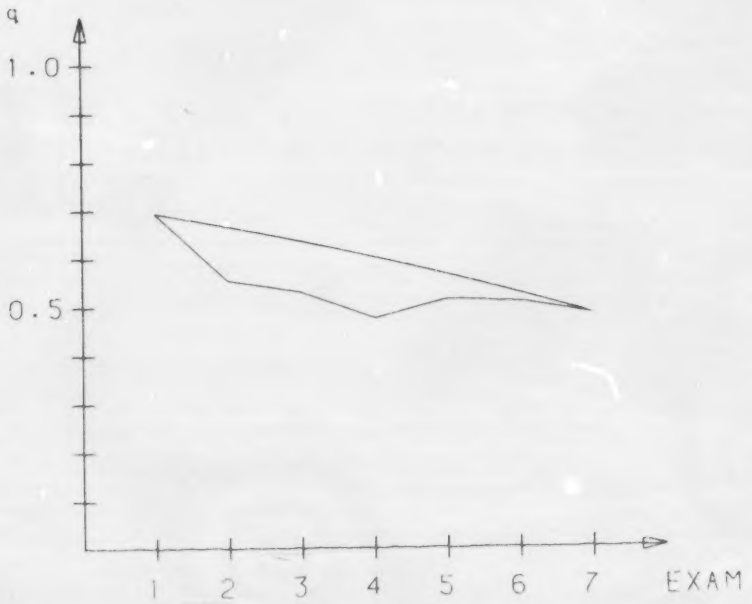

Fig. 4. Means of empirical q-values (1975-80) and theoretical q:s (smooth curve).

The correlation between the empirical and theoretical values is $r = 0.73$ ($p < 0.05$). Thus hypothesis 3 gains some support.

If the differences d_i between the theoretical and mean empirical q-values are computed and compared with the corresponding means of mean scores, table 3 is obtained.

Exam	1	2	3	4	5	6	7
d_i	0	.112	.106	.126	.051	.018	0
Mean of mean scores	12.83	10.24	9.58	8.80	12.69	11.24	15.00

Table 3.

The correlation is $r = -0.87$, which is significant ($p < 0.01$).

The obvious extension of the ideas developed in hypotheses 3 and 4 is to correct the empirical q for nonlinearity. Table 3 gives a regression line for d_i, namely $d_i = 0.313 - 0.22M_i$, where M_i is the mean (over the years) of the mean scores in exam i. Thus corrected the empirical q:s are given in fig. 5.

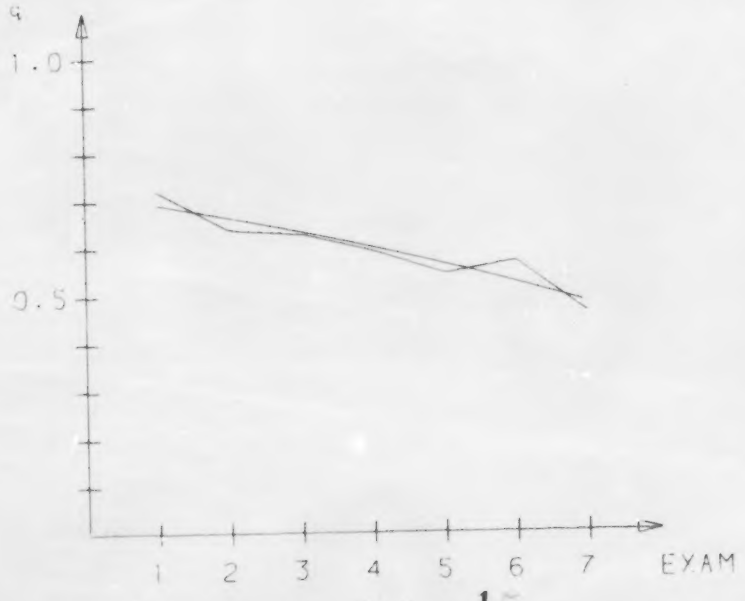

Fig. 5.

Here the average q is predicted by the two variables "mean score" and "ordinal number of examination", and the correlation now is R = 0.94 ($p < 0.01$). The correlation remains quite high if the values are not averaged over the five years in question; a conventional (multiple) regression analysis performed on the separate data of 35 examinations (5 years x 7 examinations/year) results in the multiple coefficient R = 0.81 ($p < 0.0005$).

4.3. The standard deviation

If the means of the standard deviations of the scores are computed over 1975-80 separately for each examination and for group 1 and 2, the results are those given in table 4.

Exam	1	2	3	4	5	6	7
Group 1	4.27	4.21	3.89	3.60	4.44	3.53	4.71
Group 2	3.78	4.56	4.33	4.77	4.46	4.93	5.04

Table 4. Mean standard deviations

There is a significant increasing trend for group 2, r = 0.85 ($p < 0.01$). Thus hypothesis 5 seems to get some support. On the other hand no trend is found for group 1; as this group consists of subjects whose scores are relatively low at the outset and steadily decreasing, the explanation might be that their performance gets closer to the origin in fig. 3, where the slope of the curve gets smaller and where thus an increase in the variance of performance is not reflected in an increase of variance of scores. Moreover, as group 1 grows smaller due to dropout and as those who abandon the course on the average score lower than the remaining subjects in group 1, selection reduces the variance.

5. COMMENTS

An obvious objection to equation 1 is that it implies too deterministic an approach. After all experience shows that even a few subjects who score 0 on the first examination bounce back and ultimately pass. Of course other

processes could be at work here, but without going into these one could perhaps account for these anomalies by substituting a stochastic differential equation for eq. 1.

Quite another problem is due to the fact that the mean scores of group 1 are not "true" values, due to selection as the group is decimated. As noted earlier those who drop out from group 1 perform worse than the whole group, and thus the values would undoubtedly be lower if no dropout would occur. The overall picture would, however, certainly remain the same.

There remains the assumption made in deriving equation 1, namely that the score s_a corresponding to y_a is equal to $\bar{s}_{02}$. As the mean score $\bar{s}_2$ is 14.0 it would be interesting to obtain an empirical value for s_a. Some light is shed on this problem by results obtained for the course given 1980-81 (which is not included in the data presented so far). A sample (N = 139) was presented with a question about the level of aspiration (the question was: Which mean score would you be satisfied with?). The mean turned out to be 13.8, comfortably close to the value given above for $\bar{s}_2$.

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